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Infrared Radiation Absorption by Pyrotechnic Smokes

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ABSTRACT

The infrared absorbance at wavelength 1.5 – 2.5 μm has been studied for white, orange, green and red coloured smokes. This paper describes an experimental set up, the results obtained and also discusses the potential application of smokes in attenuating infrared light assisting opto-electronic target detecting devices.

1. INTRODUCTION

The use of infrared portion of the electromagnetic spectrum has made it technically possible for the modern armies to engage targets in total darkness and through mist, haze and battlefield obscuration. This has been possible because of the development of active and passive infrared surveillance system[1]. The active infrared system radiates energy at the target to illuminate it, whilst the passive infrared system does not emit any form of radiation and hence is undetectable. One form of passive infrared system is the thermal imaging system which is an opto-electronic device and can detect infrared signature given off by heat sources. The thermal imaging system operates on the principle that all objects above absolute zero emit to some extent infrared radiation. The infrared radiation given from the object is concentrated on a thermal or photon detector and the output of the detector is amplified and the image displayed on a television monitor or light emitting diode display[2].

Extensive defence programmes include installation of thermal imaging systems in major weapon systems[3,4]. Smoke can suppress, reduce or attenuate the infrared radiation and hence prevent it from reaching the detector of thermal imaging system. Therefore, smokes could be used as a counter measure for thermal imaging system.

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In view of this technique, we have studied the infrared absorption of a few coloured smokes, as well as white screening smoke.

EXPERIMENTAL SET UP

The infrared radiation emitted by an object can be measured using the radiometer. The radiometer used in our measurements was Infrared Research Radiometer, Model 12-550 Mark II. It uses a lead sulphide detector and a spectral filter to isolate radiation of wavelength 1.5 – 2.5 μm. Only one filter was available and hence studies were conducted at 1.5 – 2.5 μm. The source of infrared radiation was a 60W electrical bulb placed at a distance of 65 meters from the radiometer. The infrared source strength was found to be 109 milliwatt/steradian-micron/cm.

Four different conventional pyrotechnic smoke formulations were prepared in the laboratory. The smoke was generated between the radiometer and the source of IR radiation. The record of IR radiation intensity versus time was obtained using a normal X-Y recorder. Figs. 1, 2, 3 & 4 show the records obtained for the various formulations. Knowing the initial infrared radiation source intensity I_0 and the average reduced infrared radiation intensity I_t (due to screening action of smoke); the transmittance and absorbance were computed.

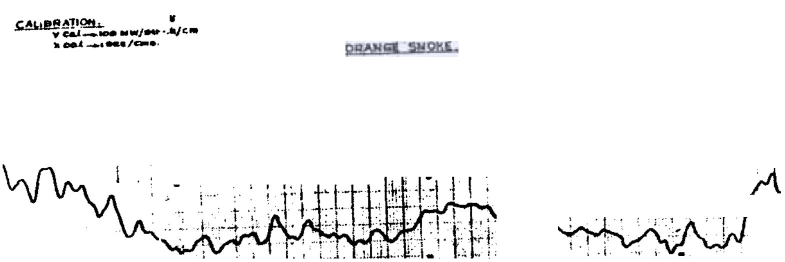

Figure 1 Record of infra-red radiant intensity *vs* time (For formulation No. 1)

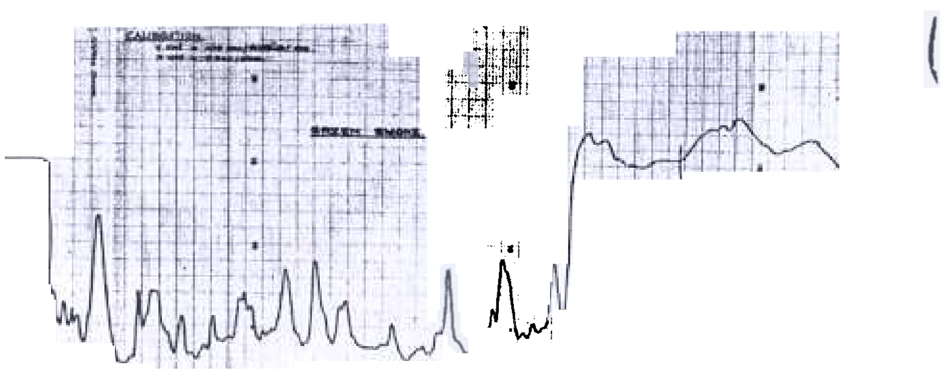

Figure 2. Record of infra-red radiant intensity *vs* time (For formulation No. 2)

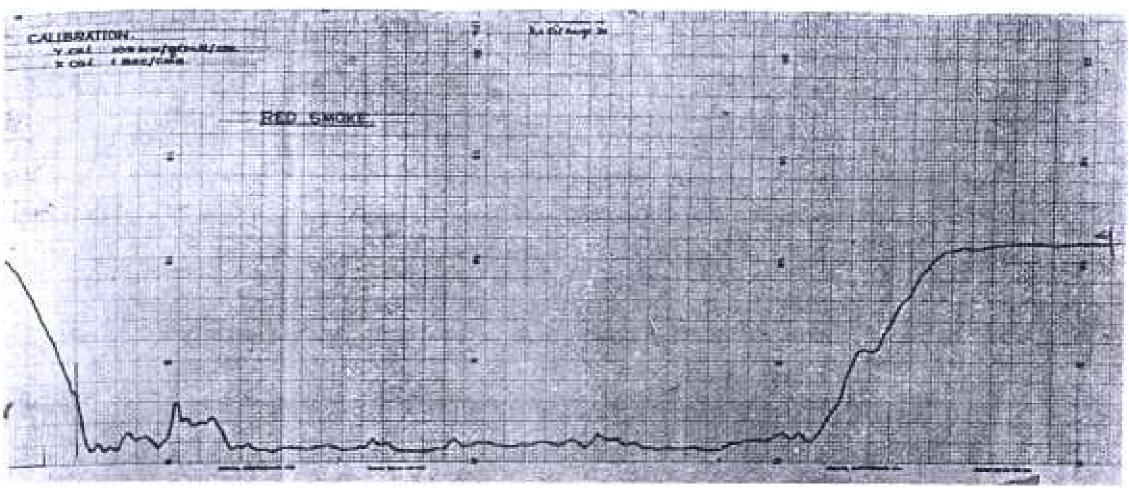

Figure 3. Record of infra-red radiant intensity *vs* time (For formulation No. 3)

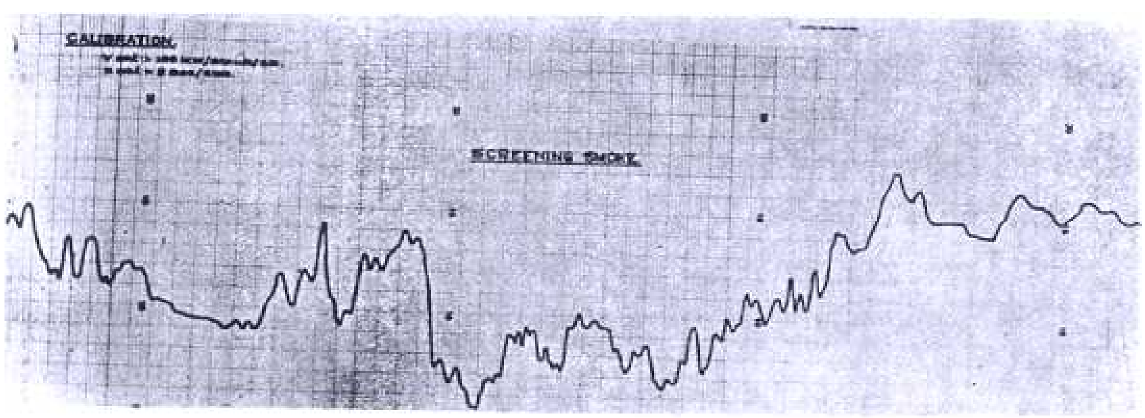

Figure 4. Record of infra-red radiant intensity *vs* time (For formulation No. 4)

3. RESULTS

The percentage transmittance values obtained for smokes from various formulations are given in Table 1. Formulation No. 3 (Fig. 3) transmits only 8.16 percent of infrared radiation of wavelength 1.5 – 2.5 μm. Formulation Nos. 1, 2 & 4 (Figs. 1, 2 & 4) transmit 55.96, 38.53 and 64.22 per cent respectively of the infrared radiation. The percentage transmittance of infrared radiation of waveleng'h 1.5 – 2.5 μm through various smokes is shown in Fig. 5.

4. DISCUSSIONS

Infrared radiation of 1.5 – 2.5 μm wavelength is absorbed in differing amounts by the smokes produced from various formulations. The smoke produced from formulation No. 3 (Fig. 3) absorbs 92 per cent of infrared radiation while the other smokes used in our study absorb infrared radiation to a lesser degree, the smoke produced from formulation No. 4 (Fig. 4) being the least efficient. The lowest efficiency of infrared absorption of smoke from formulation No. 4 (Fig. 4) is due to the particulate

Table1. Absorption of infrared radiation by pyrotechnic smokes

Formulation No.		Dyes used in formulation	Dye (%)	Colour of smoke	Burning time in secs	Infrared radiation source intensity (I_o) in MW/STR–μ/cm	Average reduced infrared radiation intensity due to screening by smoke (I_t) in MW/STR-μ/cm	Transmittance (T) $T = \frac{I_t}{I_o}$	T (%)	$\frac{1}{T}$	Absorbance (A) $A = \text{Log}\frac{1}{T}$
1		Benzene-Azo-β naphthol or dye oil orange (C.I. No. 12055)	42	Orange	60	109	61	0.5596	55.96	.78699	0.2521
2	(A)	C.I. solvent green 3 or dye arlasol green (C.I. No. 61565)	35	Green	60	109	42	0.3853	38.53	2.5953	0.4142
	(B)	C.I. solvent yellow 33 or dye quinoline yellow (C.I. No. 47000)	15								
3	(A)	C.I. basic violet 10 or dye rhodamine B (C.I. No. 45170)	20	Red	60	109	8.9	0.08165	8.16	12.2473	1.0880
	(B)	Benzene-Azo-β naphthol or dye oil orange (C.I. No. 12055)	30								
4		Hexachloroethane and zinc oxide type		White	90	109	70.0	0.6422	64.22	1.5571	0.1923

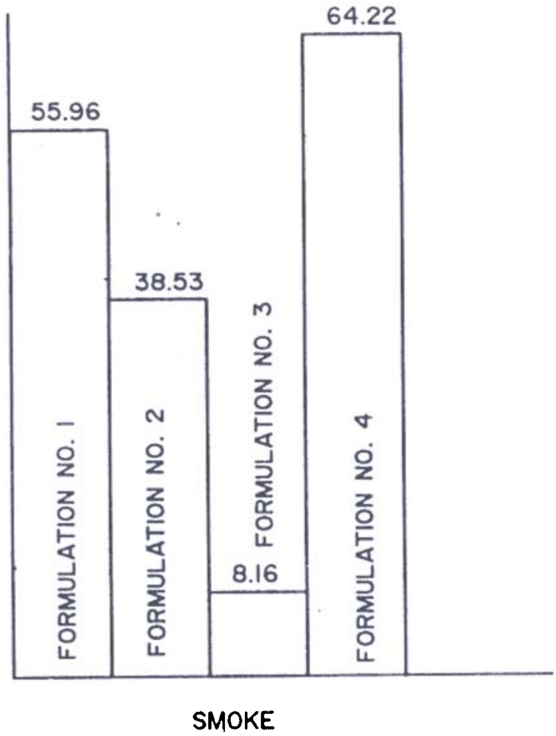

Figure 5. Percentage transmittance of infra-red radiation through smokes.

nature (zinc chloride particles) where as varying amounts of infrared absorption for the other formulation Nos. 1, 2 and 3 (Figs. 1, 2 & 3) is due to the structure of dye used (Fig. 6).

5. POTENTIAL APPLICATIONS OF ANTI INFRARED SMOKES

As discussed earlier, anti infrared smokes can defeat the thermal imaging system. Some other potential uses of such smokes have been mentioned in the literature. Smoke is an effective means of protection of ground installations against infrared reconnaissance and mapping techniques. Ground targets could also be protected from an infrared homing missile attack by using a smoke screen. The smoke dispersed from an aircraft could cause an infrared seeking missile following it to break lock[5]. Smokes can increase survivability of armoured vehicles in the battlefield by defeating or degrading the enemy opto-electronic fire control system and the laser guidance system[6,7].

6. CONCLUSION

The smoke produced from formulation No. 3 (Fig. 3) using dyes Rhodamine B (C.I. No. 45170) 20 per cent and oil orange (C.I. No. 12055) 30 per cent appears to

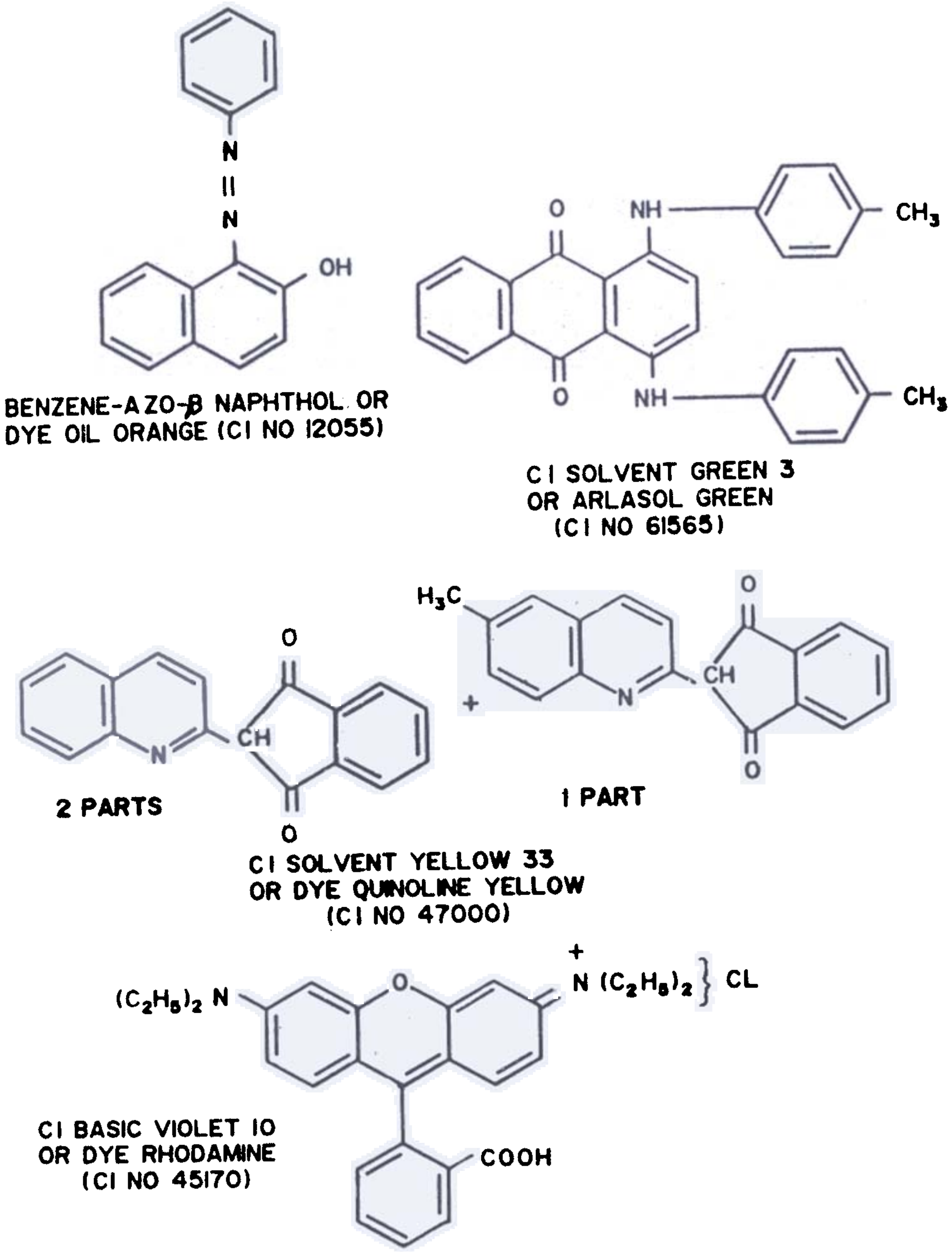

Figure 6. Dyes used in smoke formulations

have a bright prospect for defeating infrared based opto-electronic devices, laser range finder and laser target designator, operating in the near infrared region. If suitable filters for mid infrared and far infrared regions are available, further assessment of its application could be carried out.

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